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ABSTRACT

Given that theory is a crucial component of path analysis and that major theories in the social sciences either directly or by inference assume interaction, it appears that interaction has to be considered in path analytic models that reflect those theories. The use of interaction within the framework of path analytic methodology is investigated by sampling articles reporting the use of path analysis over the last 5 years. The Type VI error, the focus of the investigation, has been identified as the incorrect use of post hoc procedures and the examination of a research question using one or a limited number of designs, studies, or analyses. Fifty articles on path analysis were identified in the ERIC educational reference system. Of the 50, 19 did not test for interaction in any way, and they did not compare separate models. Twenty-six used a multiple model approach, although it was not made clear that the use of multiple models was a reflection of concern for possible interaction effects. In eight studies, analysis of variance was used prior to the inclusion of variables, and in some cases, interactions, in the model. Sixty-eight percent of the articles appeared not to consider interaction at all, even though it is fair to assume that interaction is implied or explicitly stated in the theories underlying all of the models tested. This suggests that Type VI errors are being made in a majority of studies using path analysis. An extensive table lists the articles reviewed and the methods they use. (Contains 49 references.) (SLD)

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TYPE VI ERRORS IN PATH ANALYSIS: TESTING FOR INTERACTIONS

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The purpose of this paper is to discuss and investigate the use of interaction within the framework of path analytic methodology. Bollen (1989) identified three ways that path analysis and structural equation modeling tend to be used:

1. In a confirmatory manner, which is the most traditional and is totally theory driven.
2. For testing alternative models, which may be reflective of conflicting theories, and
3. The use of structural equations in an exploratory sense, which often attempts to interweave the interpretations of the nomological nets that emerge.

One traditional requirement for using path analysis is the development of models that are then statistically evaluated. "A model is a formal representation of a theory" (Bollen, 1989, p.71). Models are derived from theories and, therefore, theory is an essential part of the path analytic process (Duncan, 1966, 1975; Featherman, 1976; Williams, 1978; Blalock, 1964, 1971; Heise, 1975, 1976, 1977; Joreskog, 1986, 1988).

Given that theory is a crucial component of path analysis, and that major theories in the social sciences either directly or by inference assume interaction, it appears that interaction has to be a considered in path analytic models that reflect those theories. Models built with the intention of testing a theory, which do not reflect the interactions of that theory, are making a statistical as well as a research design error. The authors are referring to this as a Type VI error, which is an inconsistency between the research question and the statistical model built to reflect it (Newman, Deitchman, Burkholder, Sanders, & Ervin, 1976, 1992).

A number of statistical and methodological errors have been defined in the research, starting with the traditional Type I and Type II errors. Huck and Cormier (1974) have identified Type III, Type IV and Type V errors. However, there are at least three versions of Type III error:

1. The first version has to do with the selection of an inappropriate test of significance which does not fit the characteristics of the available data.

2. This has been identified by Kaiser (1960) as an incorrect decision concerning the direction following the rejection of a false Null. For example, one may test for interaction and correctly reject the Null hypothesis, and then proceed to plot the interaction by plotting the cell means. Statistically, one should be plotting the residual means of the cells that are independent of the main effects.

3. The third version was attributed to Kimball (1957), who identified a Type III error as, "Giving the right answer for the wrong reason" (p. 133).

A Type IV error has been identified by Marascuilo and Levin (1970) as the incorrect use of post hoc procedures. Within this category one might place the inappropriate choice of a particular multiple comparison technique.

Huck and Cormier (1974) identified a Type V error as one that is committed when researchers tend to look only at their research question using one or a limited number of designs, studies and analyses. Huck and Cormier place emphasis on the importance of replication.

The Type VI error, identified by Newman et al. (1976, 1992) is the focus of this investigation. That is, the authors are investigating the potential inconsistencies between path analytic models and the theories they proport to reflect. Given that very few, if any, well developed theories in the social sciences assumes that there is no interaction among the variables inherent in the theory, and given that path analytic models should reflect the theories upon which they are based, studies using path analysis should frequently, if not always, test or consider interaction in the building of models.

The authors decided that an appropriate method for estimating the frequency of path analytic researchers considering interaction within their models, would be by

sampling 50 articles reporting the use of path analysis, over the last five years. More specifically, this paper has three objectives. They are to:

1. Review published articles on path analysis in education between 1987 and 1992, identified through an ERIC computer search.

2. Determine how often interaction is considered in the path analysis models used in those 50 articles, and

3. Identify and summarize how researchers who considered interaction, dealt with the interaction.

Methods

In an effort to identify journal articles using path analytic procedures, a literature search was conducted using the ERIC educational reference system. The key words "path analysis" and "research" were entered in a search of the 1981 to present data base. The review process involved reading the articles in order to determine whether or not the researchers considered interaction effects in their analysis. Articles were collected in reverse chronological order until a total of 50 articles were reviewed. A second reviewer read the articles to establish the reliability of the evaluations of the articles. The second reviewer continued reading the articles until 100% agreement was reached on at least 10 consecutive evaluations.

Results

The ERIC search yielded 496 entries. Most of these entries were ERIC documents. A number of the articles were methodological in nature, rather than reporting the results from a study using path analysis. Articles not available from the university library were ordered through interlibrary loan (17 articles). The sample 50 articles ranged from 1992 back to 1987 (microfiche documents and microfilm journal articles were not considered.)

Three of the first five evaluations of the articles were changed by consensus of the two reviewers. The reviewers were in total agreement concerning the next 12

articles, and the remainder of the articles were reviewed by one reviewer. However, approximately five additional articles were checked by the second reviewer and in all cases the second reviewer agreed with the first.

Of the 50 articles reviewed, 19 did not test for interaction in any way, nor did they compare separate models. In these studies the path analysis was designed to determine direct and indirect causation. Twenty-six studies used separate models and compared the model weights. In most cases this was a comparison of two models, such as males and females (e.g. Jacobs, 1991) or adopted and natural born children (e.g., Rice et al., 1988). In all but six of these studies there was no prior test of interaction (such as analysis of variance) or any other indication that the purpose of using separate models was due to the belief that interaction effects were occurring. The use of different models was limited to a comparison of differences between what might have been considered main effects. In five of the studies an interaction term was included in the path model. In all of these five cases the interaction term only dealt with first order interactions.

Discussion

In 19 of the 50 articles (more than one third) there was no indication that the researchers were sensitive to the need to consider interaction. Twenty-six of the 50 (approximately half) used a multiple model approach, however it was unclear that their use of multiple models was a reflection of their concern for possible interaction effects. It appeared that there were no apriori tests for interaction, with the exception of eight studies in which analysis of variance was used prior to the inclusion of variables, and in some cases interactions, in the model. Therefore, it appears that 15 of the 26 cases that used multiple models did so for reasons other than out of consideration for interaction. Sixty-eight percent of all of the articles reviewed appeared not to consider interaction, even though it is fair to assume that interaction is implied or explicitly stated in the theories underlying all of the models tested. Thus, there seems to be a

great possibility that Type VI errors are being made in a majority of the studies using path analysis procedures.

In addition, some of the terminology in path analytic procedures has lead to confusion. For instance, the terms "buffering" and "indirect" have been interpreted by some to be analogous to interaction. The tendency for some to consider indirect effects as taking the place or as comparable to interaction further increases the likelihood of misinterpretation. Indirect effects are a form of analysis of covariance which requires no interaction (homoscedasticity of regression slope) for a correct interpretation. Not only would it be inappropriate to interpret indirect effects, it would also be inappropriate to consider direct effects if interaction was occurring. This would be analogous to making the error of considering main effects in analysis of covariance, when interaction was significant.

This does not imply that it is not possible to consider interaction and include interaction terms in path analytic models. However, significant interaction terms make a model much more difficult to interpret, and the research presented here suggests that few attempts were made to consider interaction in any form.

Note that none of the articles reviewed considered higher order interactions (3-way, 4-way, 5-way, etc.). This is not only a problem for those conducting path analysis, but for researchers in general (including those using multiple regression). However, if the theory suggests higher order interaction, it is necessary that the path model reflects that interaction.

Most theories considering human nature suggest that a complex interaction of variables is present. When testing a causal model, it is always logical to consider the possibility that two or more of the variables may be interacting in ways that could significantly impact on the outcome. Ignoring these interactions can be extremely misleading (a Type VI error). The review of the current literature has indicated that

interaction is often overlooked, which may have led to incorrect inferences. It is hoped that this paper will sensitize researchers to the need and value of checking for potential interaction.

Table 1

Articles Reviewed and Methods Used to Test for Interaction

Author	Date	Topic	Criterion Variables	Predictor Variables	Interaction Tested
Chan, et al.	1992	Learning via constructive activity	1	9	ANOVA
Ethington	1992	Model for achiev. behav.	1	10	Term &Sep
Guelzow et al.	1991	Stress & gender in dual careers	1	4	Sep & models
Jacobs	1991	Parental/child attitudes & math grades	1	4	ANOVA & Sep
Kavale et al.	1991	Structure of learning disabilities	1	5	No test
Kember et al.	1991	Student attrition	1	10	No test
Thompson et al.	1991	Television viewer activity	1	9	Sep models
Brainerd et al.	1990	Age & forgetting	5	2	ANOVA, Term Sep. models
Camarena et al.	1990	Gender intimacy in	1	2	Sep. models
Cardon et al.	1990	Genetic correlations with reading & IQ	2	5	Sep. models
Culver et al.	1990	Model of teacher satisfaction	1	7	Sep. models
Kyrios et al.	1990	3-5 Year olds' causes	1	7	No test of behavior
Morcol et al.	1990	Residual plotting of 4 yr. & higher educ. Tech.	6	3	Sep. models
Neumann et al.	1990	Burnout in universities	1	3	No test
Pokay et al.	1990	Motivation strategies & achievement	1	9	ANOVA, Term & Sep models
Serbin et al.	1990	Gender & academic performance	1	7	Sep. models
Skaalvik et al.	1990	Academic self concept	1	4	Sep. models

Author	Date	Topic	Criterion Variables	Predictor Variables	Interaction Tested
Skinner et al.	1990	Perceived control & achievement	1	4	ANOVA
Watkins et al.	1990	Self concept, attributions, & achievement	1	5	Sep. models
Wong	1990	Job satisfaction & work centrality	2	5	Sep. models
Allen et al.	1989	Model of college withdrawal	1	6	Sep. models
Braxton	1989	Student attrition	1	6	No test
Fresko et al.	1989	Factors on tutor & tutee satisfaction	1	7	No test
Hassenfeld et al.	1989	Attitudes toward welfare	1	13	No test
Haury	1989	Locus of control & attitudes to science teaching	1	7	No test
Lapsley et al.	1989	Mental capacity & role taking	1	4	ANOVA & Sep.
McCoy et al.	1989	Computer programming & mathematical problem solving	1	6	No test
Pihl et al.	1989	Predict of active researchers	1	7	No test
Reid	1989	Social control theory	1	9	No test
Kline et al.	1987	Teenage alcohol use	4	7	No test
Mednick et al.	1987	Divorce & son's crime	1	3	ANOVA
Moline	1987	Financial aid & student	1	10	Inter. term persistence
Oetting & Beauvais	1987	Peer group and drug abuse	1	5	No test

Author	Date	Topic	Criterion Variables	Predictor Variables	Interaction Tested
Strom et al.	1987	Course difficulty & test anxiety	1	4	No test
Vaux et al.	1987	Social support	1	4	Sep. models

Note:
No test for interactions	= 19
Used separate models	= 26
Analysis of variance	= 8
Included interaction term	= 5
Tested other than separate models	= 11
Total number of articles reviewed	= 50

Table cont. on next page

Additions to TABLE 1

Ellison et al.	1992	Neonatal care & developmental pathways	15mo. - 2 4 yrs - 2 7 yrs - 4	10	Sep models
Garcia-Celay et al.	1992	Acheivement motivation in high schoolers	1	7	Sep. models
Boyes	1991	Student use of Microcomputers	2	13	No test
Cool et al.	1991	Academic achievement	1	8	Inter. term
Cambell et al.	1990	Enrollment in computer courses	2	14	Sep. models
Schebeci	1989	Attitudes & science achiev.	6	8	Sep. models
Braxton et al.	1988	Student attrition	1	8	No test
Dunton et al.	1988	Mothers' attributions & childrens' math performance	1	2	Sep. models
Jeffreys et al.	1988	Vocational student organization participation	1	8	No test
Keith	1988	Influences on learning	1	8	No test
Rice et al.	1988	IQ & home Environment in adopted or natural children	1	10	Sep. models
Smylie et al.	1988	Antecedents to teacher change	1	7	No test
Tunmer et al.	1988	Metalinguistic abilities & reading	2	4	Sep. models
Van Blerkom	1988	Gender & other variable in college students	1	9	ANOVA & Sep.
Fries et al.	1987	Genetic stability of cognitive development	1	10/8	Sep. models

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